UNITED STATES DEPARTMENT OF AGRICULTURE
RURAL ELECTRIFICATION ADMINISTRATION
TECHNICAL STANDARDS DIVISION

TWO-WAY COMMUNICATION FACILITIES FOR RURAL POWER SYSTEMS

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I. INTRODUCTION

A. General

Since the first rural power lines were energized there has been a growing need for some form of rapid two-way communication between maintenance crews and headquarters. The expansion of facilities and the growing dependence of farmers and rural industries on uninterrupted electric service makes rapid communication a vital necessity.

Rural telephones have been the backbone of communication between maintenance crews and headquarters, but in far too many instances this has proved inadequate. It is not uncommon for rural power distribution lines to extend into territory not covered by telephone service. Too, ordinary telephonic communication does not solve the problem of getting in touch with maintenance crews in the field on short notice. The usual practice of reporting in to headquarters by telephone at predetermined times is sometimes cumbersome and is often quite expensive when long distance toll calls are required. This is especially true when a relatively large number of maintenance crews are involved. The practice of maintaining emergency standby crews is costly and a waste of manpower.

The use of two-way radio and two-way power line carrier communication systems has been rapidly gaining favor as the most logical means of supplementing existing wire communication facilities.

B. Scope

The following three types of communication systems can be used successfully on rural transmission and distribution systems:

1. Two-way mobile radio, owned by the user.
2. Two-way mobile radio, leased or rented by the user.
3. Two-way mobile power line carrier telephone, owned by the user.

This report duscusses each of these types of systems with the view of presenting types of equipment, operating characteristics, propagation characteristics, available channels, and power requirements. It also discusses licensing requirements and the factors to consider when preparing cost estimates for a two-way communication system.

With this information at hand it should be possible for the prospective user of two-way communication equipment to weigh each type of system against the others.

It should be kept in mind, however, that two-way mobile communication service may still be considered to be in the experimental stage and developments with extended use may substantially change present views, including the level of costs.

II. TWO-WAY MOBILE RADIO COMMUNICATION

A. Definition

For purposes discussed herein, two-way radio communication is defined as radio communication conducted between two or more land stations, between land and mobile stations or between two or more mobile stations. Two-way radio communication between two dispatching headquarters is an example of communication between permanently located stations known as land stations. Two-way communication between a dispatching headquarters and a maintenance vehicle is an example of the land-to-mobile case. Two-way communication between a superintendent's car and a maintenance truck is an example of the mobile-to-mobile case.

This section discusses two-way radio communication in general, and in particular two-way radio communication equipment owned and operated by the using agency. Section III discusses the Mobile Radio-telephone service as supplied by the telephone companies.

B. Basic Considerations

In planning a two-way radio system several basic factors must be taken into account:

1. Area of coverage or range desired.
2. Frequency or wave length.
3. Size and type of equipment.
4. Servicing and maintenance of equipment.
5. Initial and operating costs.
6. Licensing of equipment and personnel.

Since the above factors are inter-dependent, they will be examined first independently, and then collectively in order to arrive at the best solution.

C. Frequency Allocations

At the present time two-way radio systems operated by electric utilities are licensed to operate on specified frequencies designated as "Power Utility" frequencies and "Special Emergency" frequencies or, in some instances, "Provisional" or "Experimental" frequencies. These frequencies are located in the following bands:

2 to 6 Mc band
25 to 30 Mc band
30 to 40 Mc band
72 to 76 Mc band
152 to 162 Mc band

The use of the "Special Emergency," "Provisional" and "Experimental" frequencies by electric utilities and others is temporary. The Federal Communications Commission has recently allocated 33 channels in the Utility Radio Service for the exclusive use of electric, gas, water and steam utilities and certain industry groups requiring similar radio service. The table below lists these bands and the number of channels, but the final frequencies of these channels have not yet been designated.

Frequency Band (Megacycles)		Number of Channels
25 to 30		12
30 to 40		7
72 to 76		6
152 to 162		8
	Total	33

While it is anticipated that the above channels will take care of most of the electric utility mobile communication problems, it is recognized that for longer distance communication or for satisfactory communication in certain types of terrain, much lower frequencies are required. The Federal Communications Commission has recently indicated that it will make available certain frequencies in the 2 to 6 megacycle band for use by electric utilities and others having similar communication requirements.

It must again be emphasized that frequency assignments made before the Federal Communications Commission announces its final frequency allocations must be considered as temporary, subject to change when the final assignments are made. Such change may entail additional expenditures on the part of the licensee for new crystals, antenna modifications and equipment adjustments. It is not anticipated that the frequency changes will make existing equipment obsolete. The estimated cost of changing frequency is $40 to $50 for each two-way unit. Some manufacturers have indicated that they will exchange crystals without charge within a specified period.

D. Frequency vs Range

For electric utility work, the range of a one-way land-to-mobile radio system employing a frequency in the 2 to 6 megacycle band is from 10 to 50 miles. Range depends upon the antenna types and heights and locations, power outputs, soil conductivity, noise levels and other factors. Communication over these distances at these lower frequencies makes principal use of the "ground wave" which hugs the surface of the earth. The ground wave is not limited to line-of-sight distances but is capable of traveling over hills and down into valleys. This is the chief advantange of the 2 to 6 megacycle band. A disadvantage of this band is that the sky wave component of radiation is reflected from the ionosphere and returns to earth at some point beyond, say, 50 miles, up to a distance of several thousand miles. Interference is thus propagated to distant points and likewise is received from distant points. Sky wave propagation characteristics vary considerably between day and night and between summer and winter.

Another disadvantage is that atmospheric noise commonly known as "static" is more severe on the lower frequencies than on the higher frequencies. Atmospheric static is much more severe during the summer months, and in some cases makes communication over all but the shortest distances impossible during lightning and thunderstorms.

Mobile transmitters operating in the 2 to 6 megacycle band have very inefficient antenna systems, and therefore it is not uncommon to run into considerable difficulty in establishing two-way communication at these frequencies.

For a given range, more power output is required on lower frequencies than on the higher frequencies.

For the above reasons it appears that the 2 to 6 megacycle band should be used only as a last resort for one-way land-to-mobile communication, and only when longer distances are involved accompanied by terrain features which are unfavorable for use of the higher frequencies.

The range of a two-way radio system employing a frequency in the 30 to 40 megacycle band, or in a higher frequency band, is limited to so-called "line-of-sight" distances. Actually, experience has proved that reliable communication in the 30 to 40 megacycle band can be accomplished, in some instances, over distances greater than line-of-sight by as much as a factor of 3. Line-of-sight distances imply, however, that communication is not generally feasible between two points that are screened from each other by intervening hills or mountains or by curvature of the earth. To overcome this line-of-sight handicap the obvious solution is to make the land station antenna tower as high as economically possible or to locate the antenna on a high hill or mountain.

The extreme range to be expected in the 30 to 40 megacycle band appears to be slightly greater than at the higher frequencies. The higher frequencies, however, appear to offer more reliable communication within their working range, especially in the larger cities.

By far the majority of the present two-way radio systems are operating in the 30 to 40 megacycle band. Recent technological advances have made possible the efficient utilization of the 72 to 76 and 152 to 162 megacycle bands, and the present trend is toward greater use of these higher frequencies. This trend should be encouraged. There are three principal reasons for this trend:

1. Some sky wave interference exists in the 30 to 40 megacycle band.

2. Sky wave interference is aggravated by the present over-crowded condition of the 30 to 40 megacycle band. Sky wave interference is practically non-existant at the higher frequencies.

3. Communication in cities with many tall buildings and congested areas appears more reliable at the higher frequencies.

When setting up a new two-way radio communication system, serious consideration should therefore be given to the use of the 72 to 76 megacycle band or the 152 to 162 megacycle band.

Two-way land-to-mobile communication at the very high frequencies, which include the 30 to 40, 72 to 76 and 152 to 162 megacycle bands, barring screening effect of intervening hills and mountains, can easily be accomplished over distances of 15 miles. Distances of 25 miles are possible but require high antennas, and competent engineering in the location of antennas. Reliable two-way communication at greater distances than 25 miles will in general require exceptionally high antennas, carefully located. As an alternative to the use of exceptionally high antennas, ranges greater than 25 miles may be achieved by using a land transmitter of higher power to assure greater coverage outbound and several land station receivers located strategically to obtain commensurate inbound coverage. In some cases radio relay stations may be required in lieu of land lines.

It must be borne in mind, therefore, that two-way communication systems designed to cover distances greater than 25 miles usually become much more costly and complex than systems designed to cover lesser distances.

E. Antenna Heights

At the very high frequencies, increasing the power of the transmitter will increase the sending range of the equipment. Increasing the height of the antenna will increase the range of the equipment in both sending and receiving. The use of high antennas is usually desirable but is sometimes disappointing. Many users have been disappointed in the results obtained by increasing the heights of their antennas in city areas. Transmission improves as expected but reception may not improve or may even become worse. As the antenna height is increased noise pickup sometimes rises rapidly. As a general rule, however, high antennas in rural areas usually prove satisfactory.

Certain types of antennas known as power gain antennas have the property of concentrating the radiated energy where it will do the most good. The use of a power gain antenna will accomplish the same results as increasing the transmitter power output. Frequencies in the 152 to 162 megacycle band are ideally suited for the application of power gain antennas.

Locating the antenna on a high hill or mountain is desirable if the hill or mountain is within a reasonable distance from dispatching headquarters. The transmitter and receiver must be located near the antenna, and provisions must be made for remote control of the equipment over land lines or by radio relay.

F. Remote Control

Remote control units are designed to perform the following functions:

1. Energize the remotely located transmitter from dispatching headquarters when it is desired to transmit.

2. Amplify the voice signals transmitted over the control circuit in order to make up for transmission losses.

3. Monitor the remotely located transmitter.

4. Cut off transmitter and turn on receiver when it is desired to receive.

5. Turn off all equipment when it is desired to shut down operation.

Land line remote control is usually accomplished over an ordinary telephone circuit. The local telephone company can usually supply this service for an average monthly rental of about $4 per mile. Land line remote control circuits can be made to function over any distance, but 10 to 15 miles appears to be the maximum practical limit purely from an economical standpoint. In many instances it may be desirable for the using agency to construct its own land line facilities. By utilizing existing poles on a joint use basis, a land line for remote control may be constructed for a cost of from $100 to $300 per circuit mile.

If a land line is not feasible, a radio remote control circuit may be employed. The Federal Communications Commission has allocated special frequencies for the operation of remote control radio relay units. Radio relay equipment usually operates unattended, but it should be located where it will be readily accessible for normal inspection and maintenance.

At the present time the Federal Communications Commission is allocating, on a temporary basis subject to revocation on short notice, frequencies in the order of 78 megacycles for one-way and two-way radio remote control circuits. The Commission has indicated its intention to ultimately allocate frequencies in the 952 to 960 megcycle band for this purpose, and licensing of equipment awaits only the commercial availability of 952 to 960 megacycle equipment. The Commission has indicated that when this ultra-high frequency equipment is available, many existing radio relay circuits will be required to go to the new frequencies which will, of course, obsolete the existing equipment. For this reason it may be desirable for potential users of radio controlled circuits to forestall action on the installation of such control equipment until the final frequencies are allocated and the necessary equipment becomes available. In the interim period it may be advisable to limit remote facilities to installations that make use of telephone lines for remote control purposes.

In order to get adequate two-way radio coverage it is sometimes necessary to install remotely located receivers to pick up the weak transmissions originating from distant mobile units. Remotely located receivers are particularly desirable when local noise conditions are troublesome. Remotely located pick-up receivers are usually connected with dispatching headquarters by means of a land line, but sometimes a radio relay is employed. Radio relay circuits are usually quite expensive and their cost should be balanced against the cost of an equivalent land line circuit. The question of reliability and continuity of service should also be considered.

If the difference in cost of the land line as compared with the radio relay is marginal, land line facilities are generally favored, as operation and maintenance are less expensive.

G. Selection of Channels

Experience has shown that local stations operating on adjacent channels will interfere with one another. In choosing a channel, care should be taken to insure that no other local station is being operated on the same or on the adjacent channels. In congested areas this may not be possible because of the limited number of available channels. In some instances it may be desirable for neighboring electric utilities to share the same channel, as this affords an opportunity to coordinate activities in times of emergencies.

The Federal Communications Commission is attempting to allocate channels to the various services, so that the using agencies located in the same local areas will not occupy adjacent channels. It is the responsibility of each using agency, however, to coordinate with other local using agencies in the selection of channels. It might be well to point out here that a power utility is not limited to the use of one channel, but it may apply for use of as many of the power utility channels as is deemed necessary.

H. Radiated Power Requirements

The Federal Communications Commission requires that the power which may be used by a station in the Utility Radio Service shall be no more than the minimum required for satisfactory technical operation commensurate with the size of the area to be served and local conditions which affect radio transmission and reception.

The Federal Communications Commission has set up power limitations given in terms of maximum plate input power. The figures given below are expressed in terms of power output, a more commonly used term. These figures when converted to input power fall well within the required limitations.

The transmitter radiated power requirements given here are estimates based on the ranges required to cover typical rural distribution systems. These powers may not insure complete coverage but may be considered to be suitable for the typical case.

Radiated power requirements in the 2 to 6 megacycle band:

Land station transmitter	500 watts
Mobile station transmitter	100 watts

In the 2 to 6 megacycle band the greater the power the greater the range. The length of the land station antenna should be one-half wave or one-quarter wave. Placing the antenna on a high hill or mountain would not necessarily increase the range, as the range is not dependent upon line-of-sight but is primarily dependent on radiated power.

The 100 watt transmitter rating of the mobile transmitter represents the present practical limit to which a mobile transmitter can be economically manufactured and operated. Unfortunately, mobile antennas operating at these lower frequencies are quite inefficient so that the range of the mobile transmitter is not nearly as great as the range of the land station transmitter.

Radiated power requirements in the 30 to 40 megacycle band:

Land station transmitter	60 to 250 watts
Mobile station transmitter	30 to 60 watts

In some cases 60 watts is sufficient for the land station transmitter, as the equipment is operating on essentially a line-of-sight basis. Increasing the power of the transmitter to 250 watts will increase the one-way range somewhat. This power increase may not be justifiable from an economic standpoint as a means of increasing range. Increased antenna height will sometimes accomplish a comparable range increase at a lower cost. Increasing the land station antenna height has the further advantage of acting to increase the two-way range. Increased power does have the advantage that it will generally improve mobile reception in the spotty areas on the outer fringe of the working range, and in congested areas where noise level is high. When high power is used on the land station transmitter the mobile receivers need not be maintained at absolute peak efficiency to insure reception of signals.

Power gain antennas may well be used to increase the effective radiated power. Power gain antennas installed at the land station will also effectively increase the signal strength from the mobile transmitters.

For mobile units a 30 watt transmitter will suffice in many cases, as the range of a 30 watt mobile transmitter is only slightly less than the range of a 50 watt transmitter. The cost differential between 30

watt and 50 watt transmitters is small. The principal advantage of the 30 watt transmitter is lower battery drain while idling or while transmitting.

The 50 watt mobile transmitter appears desirable when relatively long distances are involved, accompanied by inherently weak signal strengths and high noise levels at the land station receiver location.

In any event the land station transmitter will radiate stronger signals at considerably greater distances than will the mobile transmitters because of the increased height and greater efficiency of the land station antenna. Thus, one-way communication can be established at greater ranges. This factor can be used advantageously, as the mobile units may be able to maneuver into favorable positions on top of hills for returning calls that otherwise would not have been heard. Auxiliary remote pick-up receivers may be used to advantage in many situations.

Radiated power requirements in the 72 to 76 megacycle band and in the 152 to 162 megacycle band:

Land station transmitter	30 watts to 250 watts
Mobile station transmitter	30 watts

The radiated power requirements at these higher frequencies appear to be lower than for equipment operated in the 30 to 40 megacycle band, although this has not been definitely proven.

I. Estimation of Equipment Costs

There are many component units that go to make up a two-way radio communication system. In estimating costs the following items should be taken into consideration:

Land station transmitters and receivers
Land station remote control units
Remote pick-up receivers
Automatic one-way repeater units
Automatic Two-way repeater units
Antenna systems
Mobile transmitters and receivers
Test equipment and frequency monitor
Spare parts and spare units
Heavy duty batteries and oversize automobile generators
Facilities for housing station equipment
Engineering and installation service
AC power line to station equipment
Auxiliary gasoline driven power supply
Land lines for remote controlled units and pick-up receivers
Rental, lease or purchase of sites for remote equipment and pick-up receivers
Any applicable sales or excise taxes

J. Obsolescence and Depreciation

Ten years appears to be a reasonable period in estimating the useful life of a two-way radio communication system, although during the war the War Production Board released equipment and granted priority ratings on the basis of five years as the useful life of a radio transmitter.

K. Maintenance and Operation Costs

The cost of maintenance of two-way radio equipment is difficult to estimate. It depends upon the amount of usage, the severity of usage, the type and manufacture of the equipment and the competency of the maintenance personnel. Although the maintenance cost of new equipment may be lower than is indicated below, as the equipment becomes older the maintenance costs are likely to increase considerably.

Some electric utilities have contracts with local radio service companies for the maintenance of their two-way radio equipment for as little as $20 per month plus cost of replacement parts.

The maintenance experience of a number of police departments and utilities has indicated that a figure of $5 to $10 per month per transmitter-receiver unit may be considered normal for servicing charges, while $5 per month per transmitter-receiver unit is considered average for replacement parts, tubes and normal wear and tear. Thus the overall maintenance cost can be expected to run from $10 to $15 per month per two-way equipped vehicle and $10 to $15 per month for each land station.

On larger two-way radio communication systems it may be advisable to employ a full-time radio technician to maintain the equipment. Experience has shown that one competent technician on a full-time basis can maintain and keep in good repair 20 to 25 two-way units.

The operating cost of a small two-way radio system is relatively low, since it is not generally necessary to employ a full-time dispatcher. Dispatching can be handled by existing office personnel as an additional duty.

The cost of power to operate the land station equipment is small but the cost of bringing power to remotely located stations may be appreciable. The cost of power to operate the mobile equipment is reflected in increased storage battery maintenance and in replacement of the heavy duty batteries at reasonable intervals.

In arriving at an estimate of the overall yearly cost of a two-way communication system, the interest and amortization of the estimated investment should be included along with the maintenance and operation cost estimate.

L. Licenses and Regulations

The Communications Act of 1934, as amended, requires that radio transmitting stations in the United States and its possessions be licensed. The Federal Communications Commission prescribes the rules and regulations under which these stations may be operated.

A new class of service known as Utility Radio Service has been recently authorized by the Federal Communications Commission. Under this class of service, power utility stations are authorized to transmit communications essential to:

> Public Safety, protection of life or important property;
>
> Operations in connection with the transmission or distribution by wirelines or fixed pipelines of electrical power, manufactured or natural gas, water, steam;
>
> Operations in connection with the generation of electrical power manufactured gas, steam; or,
>
> Operations in connection with the maintenance of transmission or distribution facilities.

The first step in securing a station license for a two-way radio system is to apply to the Federal Communications Commission for a Radio Station Construction Permit. This application should be made on FCC Form 401-C, accompanied by FCC Form 401-A when applicable. The execution of these forms requires a detailed technical knowledge of the radio equipment to be employed. Most manufacturers of two-way radio equipment will assist their clients in preparing these applications.

When the construction permit is granted, call letters are assigned. Purchase and installation of equipment may then proceed. The construction permit will specify a maximum of eight months as the time within which construction shall be completed and the station ready for operation, unless otherwise determined by the Federal Communications Commission upon proper showing in any particular case.

Upon completion of construction of a radio station in exact accordance with the terms of the construction permit, the technical provisions of the application therefor and the rules and regulations governing the class of station concerned and prior to filing of application for license, the permittee is authorized to test the equipment for a period not to exceed 30 days, provided that the radio inspector in charge of the district in which the station is located is notified 2 days in advance of the beginning of tests.

When construction and equipment tests are completed the permittee may file application for station license on FCC Form 403. One station license is required for the land station and another station license is required for the mobile units.

When construction and equipment tests are completed in exact accordance with the terms prescribed, and after an application for station license has been filed showing the transmitter to be in satisfactory operating condition, the permittee is authorized to conduct service tests in exact accordance with the terms of the construction permit until the license is granted, provided that the radio inspector in charge of the district in which the station is located is notified two days in advance of the beginning of such tests. Service tests will not be authorized after the expiration date of the construction permit.

A first or second class radio-telephone operator's license is required of the person responsible for the maintenance of two-way radio equipment using radio-telephony. This person need not be employed as a full-time operator but may be engaged on a part-time basis. He is, nevertheless, responsible for the correct functioning of the equipment, and any adjustments to the transmitters, both land and mobile, must be made under his personal supervision.

Persons operating the land station facilities are required to have at least a restricted radio-telephone operator's permit. To obtain this restricted permit, a limited knowledge of radio laws, rules and regulations governing the use of two-way radio equipment is required. A technical knowledge of radio is not required. The examination for this permit is given by the Federal Communications Commission at its field offices at periodic intervals. This examination requires but little study and is not difficult to pass.

Persons operating land stations are required to maintain accurate records of the operation of their stations.

Operators of mobile equipment using radio-telephony below 25 megacycles are not required to be licensed, provided their transmissions are monitored and controlled by their land station operators. Operators of mobile equipment using radio-telephony above 25 megacycles are no longer required to be licensed, nor is it necessary for their transmissions to be monitored or controlled by their land station operator. They must observe existing rules and regulations, however.

Detailed information pertaining to licenses, rules and regulations may be obtained from the Federal Communications Commission, Washington 25, D. C.

III. RADIOTELEPHONE SERVICE FURNISHED BY TELEPHONE COMPANIES

A. General

In many localities the telephone industry is prepared to furnish complete two-way mobile radio facilities on a rental basis. For this type of service the telephone company furnishes all necessary equipment and maintains it. The using agency obtains station licenses, uses the same frequencies and operates the equipment in the same manner as if it were purchased. The cost of this type of service depends entirely upon the needs of the user. Estimates may be obtained from the local telephone company.

The telephone industry has recently announced other plans to make available to the public a common carrier mobile radiotelephone service. This service will enable subscribers to make and receive telephone calls to and from any other subscriber connected to the general telephone system.

From preliminary surveys, it is expected that this mobile service will be used initially by concerns or individuals where it is important that headquarters keep in touch with their various drivers or vice versa. This might include such businesses as: ambulance services, armored car services, burglar and fire alarm services, construction contractors, doctors, express companies, food distributors (meat packers, dairies, bakeries, etc.), newspapers, oil companies, pick-up and delivery services serving department stores and other retail establishments, public service companies (electric light and power, gas, water, steam, transportation and communication), refrigerator services, taxicab companies, trucking companies, boat operators and railroads.

B. Service for Metropolitan Areas

Frequencies in the 152-to-162 megacycle band will be used to provide service for the larger metropolitan areas. The initial program which should be well under way by the end of 1946 calls for the installation of urban mobile service in the following cities:

East	Central	South	West
Philadelphia	St. Louis	Houston	San Francisco
Pittsburgh	Chicago	Miami	Denver
Washington	Milwaukee	Memphis	Salt Lake City
Baltimore	Cincinnati	Atlanta	Los Angeles
Boston	Cleveland	New Orleans	Seattle
New York	Columbus	Ft. Worth	Portland
Newark, N.J.	Detroit	Birmingham	
Providence	Indianapolis	Dallas	
Springfield, Mass.	Oklahoma City	Norfolk	
Worcester	Dayton	Richmond	
	Kansas City	Louisville	
	Akron		
	Toledo		
	Minneapolis		
	Des Moines		
	Omaha		

Provision of service in other cities is expected to follow.

C. Service for Highways

By locating transmitting and receiving stations at suitable points along principal highways, communication can be provided with mobile units traveling along the highways. Transcontinental highway mobile service may eventually be established. Frequencies in the 30 to 44 megacycle band will be used for the service along the highways.

The area in which communication may be maintained is not necessarily limited to the highways but can be made to cover a considerable distance on either side of the highways. Ranges of transmission of 25 miles or more from these stations may be expected in many situations.

As mobile telephone service is expanded along the highways, the useful operation areas will embrace more and more rural electric distribution systems throughout the country. It, therefore, appears that this type of two-way radio communication may be suited for electric utility dispatching purposes in rural areas as well as in urban areas, provided a satisfactory system of priority of use during emergencies can be worked out.

Mobile telephone service is now being installed between Chicago and St. Louis, Boston and Washington, New York and Buffalo via Albany, Cleveland and Cincinnati via Columbus and between Los Angeles and San Diego. In addition, radiotelephone stations are to be established at Pittston, Pa., Tulsa, Oklahoma, Austin, Texas and San Antonio, Texas. These latter stations are not yet associated with particular routes.

Since highway stations will be established in other locations, it would seem desirable in any particular case to determine from the local telephone company its plans for providing highway service.

Where large volumes of intra-company traffic are involved or where the traffic is of a special nature, a private basis of operation may be warranted. Police, power companies, taxicab concerns and others may have such requirements. The telephone companies have indicated that they are ready to provide the equipment for such private systems, install and maintain it on a rental basis.

D. Classes of Service

The announced plans offer three categories of service:

1. General Service
2. Dispatching Service
3. Signaling Service

General service will provide service between any two mobile stations or between a mobile station and a wire telephone.

Dispatching service will provide service only within range of the transmitters and receivers serving the subscribers' area. This service provides for two-way communication between a specified land terminal furnished as part of the service and certain designated mobile units where the need is for relatively frequent but brief communication.

Signaling service will provide a one-way service whereby the driver of a mobile unit on receipt of a signal, audible (non-locking) and visual (locked in), will know that he should take some prearranged action such as to call his headquarters from a convenient telephone.

Service can be provided to a subscriber on two alternate bases. One basis makes use of mobile equipment furnished and maintained by the telephone company. The other basis makes use of mobile equipment purchased from a supplier and maintained by the user.

E. Charges for Service

Charges for mobile service area messages are to be calculated on the number of message units used. A message unit comprises factors of time and distance. Charges for toll messages, i.e. where the wire telephone is outside of the mobile service area of the land station, approximate existing long distance toll charges.

In many instances the charges for radio service as furnished by telephone companies appear to approximate the cost of service where the equipment is owned and maintained by the user.

Further detailed information on this radiotelephone service and approximate dates when it will become available in a particular community may be obtained from the local telephone company serving the community.

IV. TWO-WAY MOBILE POWER LINE CARRIER COMMUNICATION

A. General

Recent advances in power line carrier current communication have demonstrated the practicality of so-called "induction radio" or carrier induction systems for mobile communication. Power line carrier signals impressed on electric transmission or distribution lines will travel for many miles along the wires, setting up a strong induction field in the immediate vicinity of the lines. A mobile unit coming within the influence of this field can receive the signals and establish two-way communication with another favorably located mobile unit or with a fixed station located at some point on the line.

Carrier induction systems are particularly adaptable to rural electric transmission and distribution circuits for one-way and two-way mobile dispatching purposes. A number of these power line carrier systems have been used throughout the country. Recent new developments in power line carrier current coupling capacitors and other devices have reduced costs considerably so that carrier induction systems can offer serious competition to conventional radio dispatching systems.

A power line carrier system offers several advantages:

1. It does not generally require licensing of stations or operators by the Federal Communications Commission.

2. Interference with other stations can be corrected more easily.

3. Its use is not generally limited by regulations.

4. The keeping of logs is not required.

5. Since the carrier current energy is principally confined to the immediate vicinity of the power lines, a certain amount of privacy is afforded.

6. Power output requirements are low.

7. The cost is low for long range operation.

Several reputable manufacturers are now engaged in developing two-way mobile power line carrier dispatching systems. This equipment is expected to appear on the market early in 1947.

B. Types of Equipment

Two-way mobile units may be classified into two principal types according to the method of coupling employed. One type makes use of a large loop antenna mounted on the vehicle. This loop antenna makes it possible to transmit from the vehicle without making any physical connection to the line. The only requirement for transmitting is that the vehicle be close enough to the line to insure adequate electromagnetic coupling with the line.

The second type of equipment makes use of a portable hot-stick coupling capacitor. With this unit it is necessary to attach the hot-stick coupling capacitor to the line by means of a long pole. In many instances it is not necessary to attach the hot-stick coupler direct to the high voltage line, as coupling to any parallel line or wire fence will frequently suffice. The principal advantage of capacitor coupling is that extremely long range two-way communication is possible because of the higher coupling efficiency.

In lieu of the loop antenna or the hot-stick coupling device, use can be made of permanently installed coupling capacitors located at convenient points throughout the system. Permanently installed loops have proved satisfactory in some instances.

Frequency modulation or amplitude modulation may be employed in mobile power line carrier dispatching systems. There is evidence that FM offers some advantage over AM in discriminating against noise, even when low deviation ratios are used. This has not been definitely confirmed, however.

C. Frequencies Used

Power systems have long used frequencies from 50 to 150 kilocycles for power line carrier communication. Higher frequencies have been used but offer the disadvantage of higher attenuation and greater radiation difficulties. The problems of standing waves, reflections and interference become more acute with the higher frequencies.

From the foregoing it becomes apparent that the frequencies from 50 to 150 kilocycles are best suited for power line carrier dispatching systems. In selecting a particular frequency from within this band, care must be taken to coordinate with all power systems and communication systems whose lines are adjacently parallel to the lines of the power system to be equipped. If two or more services, having adjacently parallel lines, occupy or share a common frequency, inductive interference will likely result. Consideration must also be given to other carrier current facilities utilizing the same conductors. This problem is usually solved equitably by having the using agencies allocate the frequencies among themselves.

D. Range

The range of a two-way mobile power line carrier dispatching system depends primarily upon the following factors:

1. Extent and type of the transmission or distribution network.
2. Transmitter power output.
3. Receiver sensitivity.
4. Method of coupling the mobile units to the line.
5. Line noise levels.

On rural distribution circuits, two-way ranges up to 75 miles, without repeaters, are not uncommon when coupling capacitor devices are employed by

the mobile units. Ranges up to 40 miles are possible when loop coupling is employed. Loop coupling has not proved too satisfactory for truck to truck communication, but is satisfactory for mobile to fixed station communication, provided the distances involved are not too great.

A mobile unit may receive calls or one-way communication may be established whenever the mobile unit is within 100 to 200 feet of the power lines. In order to return a call, the mobile unit must be close to the power line.

Power line carrier signals are not confined to the power line on which they were originally impressed, but are transferred by induction from phase to phase and to nearby parallel communication wires and to other electric circuits. Thus it is possible to receive the signals in a mobile unit that is far removed from its own system's lines but near other lines that have a parallel exposure at some point. This is decidedly advantageous in the case of rural power distribution lines whose rights-of-way do not always run along the roadside. For receiving the calling signals, use may be made of existing communication lines and other electric circuits along the highway. For returning calls the mobile unit should return to its own system's lines. Possible disturbances to other systems and methods of their elimination are referred to elsewhere in this section.

Automatic continuous calling on the part of the fixed station can be used as a means of insuring reception of signals by the mobile units. If the vehicle is not near the power line at the time the call is originated, the calling signal can be continued, automatically, until the vehicle comes within receiving range and returns the call.

E. Power Output Requirements

Experience has indicated that transmitter power output requirements are relatively small. A mobile transmitter power output of 10 to 20 watts will prove adequate in most cases, while a fixed station transmitter power output of 20 to 50 watts will generally suffice.

F. Linetraps, Chokes and By-passes

It is not generally necessary to isolate with chokes and linetraps the lines on which the carrier currents are impressed. Linetraps may have to be used, however, in cases where it is specifically desired to confine the carrier current energy to a particular section of line. The use of chokes can be held to a minimum, as bridged transformers and most branch circuits do not appreciably attenuate the carrier current energy. However, there is one condition that must bear special treatment; the case of the one-quarter wave tap.

Any branch circuit or tap whose electrical length approaches one-quarter wavelength, or any odd multiple thereof, acts as a short-circuit to the carrier signals. These taps must be electrically lengthened by the

insertion of choke coils. For rural distribution circuits these choke coils are relatively inexpensive. Under certain conditions, loop circuits also have a detrimental effect. This too is correctable.

Capacitors used for power factor correction will act as a short-circuit to the carrier currents. Insertion of choke coils in the capacitor leads will eliminate this difficulty without affecting the normal functioning of the capacitor.

In many cases it has been found unnecessary to provide carrier current by-passing devices at circuit breaker locations or switching points. The carrier current signals have a tendency to jump open switches, circuit breakers and broken conductors by induction. This is an advantage, as communication is usually needed during switching operations or when the power circuits are inoperative.

G. Remote Control and Relaying

In many cases the lines on which the carrier currents are impressed do not extend directly to the dispatching headquarters. Since it is usually necessary to locate the fixed transmitter and receiver on the power line itself, it may be necessary to utilize a remote control unit operated from dispatching headquarters. Use can be made of a leased telephone circuit, or a remote control circuit can be installed by the user. A remote control circuit will rarely exceed a few miles in length because of the usual proximity of a dispatching headquarters to its power lines.

On some large power transmission or distribution systems it may be necessary to install one-way or two-way relaying stations to boost the weak signals in the outlying areas. Relaying stations or separate transmitting and receiving stations may be required for simultaneous dispatching operations on two or more distribution systems not directly interconnected.

H. Cost Estimates

The cost of a two-way mobile power line carrier system will in general be comparable to the cost of a two-way radio system of the same number of land and mobile stations.

The maintenance problem for power line carrier dispatching equipment is similar to that of radio but not quite as severe because very close tolerances of frequency and circuit constants are not required. This should reduce maintenance costs considerably under that of radio. An estimated cost of maintenance services and replacement parts is $5 to $10 per month for each two-way unit.

J. License Requirements

Power line carrier devices do not usually require licensing by the Federal Communications Commission, nor do operators have to be licensed to use the

equipment, provided certain requirements are met. These requirements, set up by the Federal Communications Commission, specify that:

1. Such apparatus shall be operated with the minimum power possible to accomplish the desired purpose.

2. The best engineering principles shall be utilized in the generation of radio-frequency currents so as to guard against interference to established radio services.

3. In any event, the total electromagnetic field produced at any point a distance of $\frac{157{,}000}{f(kc)}$ feet from the apparatus shall not exceed 15 microvolts per meter.

4. The apparatus shall conform to such engineering standards as may from time to time be promulgated by the Federal Communications Commission.

If the power line carrier equipment does cause interference to established radio reception, licensing may become necessary.

The Federal Communications Commission, upon request, will inspect and test carrier current apparatus, and on the basis of such inspection and test, will formulate and publish findings as to whether such apparatus does or does not comply with the conditions described above. They will issue a certificate specifying conditions of operation to the party making such request.

Reputable manufacturers are conversant with the rules that apply to the functioning of power line carrier equipment, and their equipment is designed and manufactured in accordance with these rules.

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